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Propulsion cell for a device in an aquatic medium

The invention relates to an electrical cell for the propulsion of a device in an aquatic medium.

The propulsion of devices in an aquatic medium, especially when these devices of the underwater type are moving, at least for a short while in the submerged state, requires the provision of a propulsive energy, such as electrical energy, under conditions of power, duration and modulation by successive ranges which are well determined.

This is especially the case with underwater attack, response or observation devices launched from another carrying device, such as a submarine, such launched underwater devices then being subjected to a generally brief launch stage or phase followed by a longer cruise stage or phase.

The supply of electrical energy to such launched underwater devices must then meet very specific criteria in respect of electrical power delivered and duration of delivery of this energy, in order to enable the launched underwater devices to fulfil their mission in accordance with a pre-established programme.

Under these conditions, the use of conventional electrical energy sources, such as lead accumulator batteries, cannot be accepted owing, on the one hand, to the electrical power required to ensure such a function and, on the other hand, to the inert mass necessary in order to use such conventional sources of electrical energy.

The known electrical energy sources of the prior art of the thermal cell type generally enable substantial electrical

power to be delivered. However, they require the provision of substantial thermal energy in order consequently to permit the provision of electrical power.

Therefore, such sources cannot be used for mission times of aquatic devices, especially underwater devices, exceeding some tens of seconds, owing to the major difficulty encountered in providing such an amount of electrical energy beyond such a time, from thermal sources on board such devices, especially when the latter are submerged.

The object of the present invention is to overcome the disadvantages of traditional electrical cells or sources of electrical energy which cannot be considered for immediate use in the context of the operational constraints mentioned above.

In particular, the present invention relates to the use of an electrical cell for the propulsion of a device in an aquatic medium, which cell permits the delivery of electrical power necessary and sufficient for the propulsion of this type of device in accordance with a launch phase followed by a cruise phase, over distances which may extend to 10 to 20 kilometres.

Furthermore, the present invention relates also to the use of an electrical cell for the propulsion of a device in an aquatic medium, which cell permits the delivery of the above-mentioned electrical power for a period of the order of from 30 to 45 minutes.

In addition, the present invention relates also to the use of an electrical cell for the propulsion of a device in an aquatic medium, which cell has a specific structure

permitting, on the one hand, the storage of this electrical propulsion cell, which is inert in the absence of any activation, for a long period, for example several months, under optimum safety conditions, then the structural and/or functional integration of this cell in a device, for exploitation in the context of an operational mission, on simple activation when the electrical propulsion cell is immersed in an aquatic medium.

Finally, the present invention relates also to the use of an electrical cell for the propulsion of a device in an aquatic medium permitting the execution of missions of a non-destructive nature, the electrical propulsion cell, when the device has returned to its place of origin, being capable not only of being re-used, after reconditioning, but also of being stored under conditions of safety and reliability similar to those of a first use.

The electrical cell for the propulsion of a device in an aquatic medium, to which the present invention relates, is noteworthy in that it comprises at least, in a sealed cell body, a first chamber forming a housing comprising an auxiliary electrical cell and a command and control module for the electrical propulsion cell, a second chamber forming a housing comprising a main electrical cell of the electrochemical type, this second chamber being provided with members for the controlled admission and the regulation of a flow of water from the aquatic medium into this second chamber, which forms a reservoir, in order to form, after the command to admit water from the aquatic medium, an electrolyte for activating the main electrical cell, and a third chamber forming a housing comprising a module for triggering the admission by suction of water from the aquatic medium and the discharge by escape of effluents

resulting from the chemical reaction of the main cell into the aquatic medium, from an admission valve and an escape valve, respectively, which are mounted in this third chamber, the command and control module of the electrical propulsion cell permitting the activation of the auxiliary electrical cell in order to generate electrical energy temporarily during a stage of launching this device in an aquatic medium, and the triggering of the admission by suction of water from the aquatic medium and of the discharge by escape of effluents in order to produce electrical energy from the main electrical cell during a cruise phase.

The electrical cell for the propulsion of a device in an aquatic medium, to which the present invention relates, can be used for the propulsion of devices of any type in an aquatic medium, such as, in particular, a torpedo, a reconnaissance or exploration device or submarine, a surface device, for example.

The present invention will be better understood on reading the description and referring to the drawings hereinafter in which:

- Figure 1a is, purely by way of illustration, a sectional view, taken on a longitudinal plane of symmetry, of the electrical cell for the propulsion of a device in an aquatic medium, in accordance with the subject-matter of the present invention;

- Figure 1b shows purely by way of illustration various signal timing diagrams representing a specific operating mode of the electrical cell for the propulsion of a device

in an aquatic medium, to which the present invention relates.

A more detailed description of the electrical cell for the propulsion of a device in an aquatic medium according to the subject-matter of the present invention will now be given in conjunction with Figure 1a and then Figure 1b.

As can be seen in the above-mentioned Figure 1a, the electrical cell to which the invention relates comprises at least, in a sealed cell body marked 0, a first chamber 1, a second chamber 2 and a third chamber 3, each of the above-mentioned chambers forming a housing.

The first chamber 1 comprises an auxiliary electrical cell marked 1_0 and a command and control module marked 1_1 for the electrical propulsion cell.

The second chamber 2 comprises a main electrical cell marked 2_{11}, this main electrical cell advantageously being of the electrochemical type in order to operate under the conditions which will be explained hereinafter.

The second chamber 2 is also provided with members for the controlled admission and the regulation of a flow of water from the aquatic medium into the second chamber 2, which forms a reservoir, in order to constitute, after the command to admit water from the aquatic medium into the above-mentioned reservoir, an activation electrolyte marked 2_0, the function of which is of course to activate the main electrical cell 2_{11}.

Finally, the third chamber 3 comprises a module for triggering the admission by suction of water from the

aquatic medium and the discharge by escape of the effluents resulting from the chemical reaction of the main cell into the aquatic medium, the operations of admission by suction and discharge by escape of the effluents being effected from an admission valve 3_2 and an escape valve 3_3, respectively, mounted in the third chamber 3.

The triggering module bears the reference 3_4 in Figure 1a. It permits the triggering of the admission by suction of water by means of the admission valve 3_2 and, respectively, the command to discharge the effluents by means of the escape valve 3_3, as will be described later on in the description.

According to a particularly advantageous aspect of the electrical cell for the propulsion of a device in an aquatic medium, to which the present invention relates, the command and control module 1_1 of the electrical propulsion cell, which module is located in the first chamber 1, permits the activation of the auxiliary electrical cell 1_0 in order to generate electrical energy temporarily during a stage of launching the device in an aquatic medium and permits the triggering of the admission by suction of water from the aquatic medium and the triggering of the discharge by escape of the effluents in order to produce electrical energy from the main electrical cell 2_{11} during a so-called cruise phase.

With reference to Figure 1a, the auxiliary electrical cell 1_0 and the main electrical cell 2_{11} are controlled sequentially by the command and control module 1_1 of the electrical propulsion cell located in the first chamber 1 and are connected respectively to a main and secondary electrical energy distribution network.

In a general manner, it is pointed out by way of non-limiting example that the auxiliary cell and the main cell deliver electrical voltages having substantially different nominal values V'_N, V_N and they can therefore each be connected respectively to a main and secondary electrical energy distribution network, these networks of course being protected and isolated by diode connections, for example. These connections of the conventional type are not shown in the drawings.

In addition, the auxiliary electrical cell 1_0 is advantageously formed by a set of thermal cell elements started up by pyrotechnic ignition, for example.

The object of the auxiliary cell 1_0 is to supply electrical power to the device moving in an aquatic medium during the launch phase in particular, that is to say, at the beginning of the mission of the above-mentioned device, and during a phase in which the device is at a distance from the starting point not exceeding a few hundred metres.

The auxiliary cell 1_0 thus supplies the energy to the engine for the propulsion of the device moving in an aquatic medium under substantially reduced power and also to all the members of the electrical cell for the propulsion of a device in an aquatic medium, in accordance with the subject-matter of the present invention, as will be described later on in the description.

Therefore, the auxiliary cell 1_0 may advantageously be formed by four thermal cells connected in two parallel branches of two cells in series, for example.

The two parallel branches are advantageously each isolated by a diode with respect to a reverse voltage which may originate from the main cell or from the other parallel branch constituting the auxiliary cell 1_0.

Each of the thermal cells making up the auxiliary cell 1_0 is advantageously ignited by double pyrotechnic ignition by means of an ignition box not shown in the drawings.

In a non-limiting preferred embodiment, a first thermal cell is started up as soon as the device moving in an aquatic medium is launched, on the basis of a signal delivered externally by a system for launching the device moving in an aquatic medium, for example.

The above-mentioned signal, such as a rectangular wave form voltage for a predetermined period, can then enable an electrical capacitance located in the ignition box to be charged. The capacitance is then discharged onto the pyrotechnic igniters of the thermal cell that was subjected to the ignition operation first. The other three thermal cells making up the auxiliary cell 1_0 are then ignited by the electrical energy supplied by the first thermal cell subjected to the ignition process. This operation is possible as soon as the first thermal cell ignited provides sufficient nominal voltage.

In a non-limiting embodiment, the duration of operation of the auxiliary cell 1_0 does not exceed three seconds.

In a non-limiting embodiment, the auxiliary cell 1_0 permits the delivery of a maximum no-load voltage of the order of 250 V for an average power of 45 kW.

The electrical energy delivered by the auxiliary cell 1_0 is delivered on a main electrical energy distribution network and on a secondary network, which is of course connected in a conventional manner to the device which is to be supplied temporarily by the auxiliary cell 1_0.

As regards the members for the controlled admission and the regulation of a flow of water from the aquatic medium into the second chamber 2, as shown in Figure 1a, these advantageously comprise a motor-driven pump unit marked 2_4, the suction nozzle of which is connected to the valve for the admission of water from the aquatic medium, which valve bears the reference 3_2 in Figure 1a, and the outlet nozzle of which delivers the water sucked in from the aquatic medium directly into the second chamber 2 forming a reservoir, in order to form the activation electrolyte and to immerse the main electrical cell 2_{11} in the above-mentioned activation electrolyte 2_0.

As is also shown in Figure 1a, the suction nozzle 2_5 of the motor-driven pump unit 2_4 is connected to the admission valve 3_2 by way of a pipe 2_1.

The connection between the suction nozzle 2_5 and the valve 3_2 for the admission of water from the aquatic medium by way of the pipe 2_1 can be effected directly or by means of a flow regulator bearing the reference 2_3 in Figure 1a.

The above-mentioned flow regulator 2_3 enables the rate of admission of water from the aquatic medium into the reservoir formed by the chamber 2 to be regulated in a non-limiting preferred embodiment, as will be described later on in the description.

Furthermore, the members for the controlled admission and the regulation of a flow of water from the aquatic medium into the second chamber 2 advantageously comprise, as shown in Figure 1a, a thermostatic valve 2_8 connected to the main electrical cell 2_{11}. The thermostatic valve 2_8 regulates the admission of the activation electrolyte 2_0 into the main cell 2_{11} in order to trigger the activation of the main electrical cell by electrochemical reaction, as will be described later on in the description.

Finally, the members for the controlled admission and the regulation of a flow of water from the aquatic medium into the second chamber 2 comprise a device for the circulation of the activation electrolyte and the separation of the effluents thereof.

As shown in a non-limiting manner in Figure 1a, the device for the circulation of the activation electrolyte and the separation of the effluents advantageously comprises an inlet nozzle 2_{71} connected to the internal cavity of the main electrical cell 2_{11}, the latter containing, in steady state, the activation electrolyte, a first outlet nozzle 2_{72} connected in the vicinity of the suction nozzle 2_5 of the motor-driven pump and a second effluent outlet nozzle 2_{73} which is connected by way of a pipe 2_2 to the discharge valve 3_3 located in the third chamber 3.

In addition, as shown in a non-limiting manner in Figure 1a, the second outlet nozzle 2_{73} of the device for circulation and separation is connected to the effluent discharge valve 3_3 located in the third chamber 3 by means of a mode valve marked 2_6 which permits the orientation, in a first position, of the effluents towards the effluent discharge valve 3_3, when the main electrical cell is started up during the

launch phase, and, respectively, in a second position, of the activation electrolyte towards the suction nozzle 2_5 of the motor-driven pump, in order to generate closed-loop circulation of the activation electrolyte 2_0 in the main electrical cell during the cruise phase.

Finally, the thermostatic valve 2_8 is advantageously formed by a three-way valve receiving at least on one of the paths a direct flow FD of activation electrolyte 2_0 drawn from the second chamber 2 forming a reservoir and on a second path a derivative flow of activation electrolyte passing by way of a heat exchanger 2_9, the above-mentioned derivative flow Fd of activation electrolyte being maintained at a substantially constant temperature by the heat exchanger.

The thermostatic valve 2_8 delivers on a third path from the direct flow and the derivative flow at a substantially constant temperature acting as a reference temperature a flow of thermostatically-controlled activation electrolyte marked 2_{10} at a substantially constant temperature to the internal cavity of the main electrical cell 2_{11}.

The operating mode of the members for the controlled admission and the regulation of a flow of water from the aquatic medium into the second chamber and in particular the device for the circulation and separation of the activation electrolyte and the effluents is as follows:

- the set of elements making up the above-mentioned members is basically intended to regulate the thermal equilibrium of the main cell 2_{11} and of course to evacuate the effluents. This regulation is effected by the circulation of the activation electrolyte of the main cell, the operation of which is as follows:

- the motor-driven pump unit 2_4 pressurizes the reservoir, that is to say, the whole of the second chamber 2 in which the electrolyte is stored.

The circulation of the activation electrolyte is then established by means of the thermostatic valve 2_8 which, thanks to its three-way circuit, enables the direct flow FD coming from the reservoir formed by the chamber 2 and the derivative flow Fd passing by way of the heat exchanger 2_9 to be mixed.

The resulting electrolyte mixture, i.e. the flow of activation electrolyte 2_{10}, is then at a substantially constant temperature owing to the operation of the thermostatic valve 2_8 which enables the reference temperature given by the derivative flow Fd passing through the heat exchanger 2_9 to be maintained by adjusting the incoming flows.

The flow of activation electrolyte 2_{10} is then delivered to the internal members of the main cell 2_{11} of the electrochemical type in order to irrigate the internal members thereof at a rate of flow controlled by the motor-driven pump unit 2_4.

Specifically, the main cell 2_{11} is advantageously constituted by a stack of electrochemical couples irrigated by the flow of thermostatically-controlled activation electrolyte 2_{10} in order to bring about the chemical reaction of the cell which enables the corresponding electrical energy to be generated.

On leaving the main cell 2_{11}, the activation electrolyte is collected in order to be routed by the inlet nozzle 2_{71} of the effluent separator 2_7.

The effluent separator may advantageously be constituted by a gas separator based on the principle of centrifugation, as a function of the type of electrochemical reaction brought into play in the main cell 2_{11}.

The gas separator thus separates two phases, a first liquid phase corresponding to the recycled activation electrolyte sent back to the motor-driven pump unit 2_4 by means of the mode valve 2_6 and a second gaseous phase which is discharged to the aquatic medium by way of the pipe 2_2 and the effluent discharge valve 3_3.

It will thus be appreciated that the function of the mode valve 2_6 is to switch the flow of recycled activation electrolyte either to the motor-driven pump unit 2_4 during closed-circuit operation of the assembly in the course of the cruise phase, or, where appropriate, to an evacuation to the aquatic medium at the end of the mission, for example, in particular during a mission of a non-destructive nature, by means of the discharge valve 3_3.

It will of course be appreciated that the mode valve 2_6 is controlled by the command and control module 1_1 of the electrical propulsion cell, as will be described in more detail later on in the description.

A non-limiting preferred embodiment of the assembly of the electrical cell for the propulsion of a device in an aquatic medium, to which the present invention relates, will now be given in conjunction with Figure 1a and Figure 1b when the

main electrical cell of the electrochemical type is an AgO-Al cell.

Under the above-mentioned conditions, the electrical propulsion cell comprises a main electrical cell 2_{11} of the electrochemical type formed by an electrochemical block constituted by a stack of AgO-Al electrochemical couples located in the cavity of a sealed shell module 2_{11a}. The above-mentioned sealed module comprises, for example, a plurality of electrochemical couples 2_{11b} which are connected in parallel and which of course permit the circulation of the flow of thermostatically-controlled activation electrolyte 2_{10}.

As shown in Figure 1a, the sealed module is connected, on the one hand, to the thermostatic valve 2_8 at the base of the sealed module 2_{11a} and, on the other hand, to the device 2_7 for the circulation of the electrolyte and for the separation of effluents, at the inlet nozzle 2_{71} of the latter.

The main electrical cell of the electrochemical type is also formed by a reserve of anhydrous sodium hydroxide, the electrochemical block and the anhydrous sodium hydroxide being located in the second chamber 2 forming a reservoir. In Figure 1a, the reserve of anhydrous sodium hydroxide has been represented by crystals represented by crosses, which crystals are not completely diluted in the water from the aquatic medium admitted into the chamber 2.

On the admission of water from the aquatic medium, the triggering of the activation of the main electrical cell brings into play, with the AgO-Al electrochemical couples,

the anhydrous sodium hydroxide and the water, a main electrochemical reaction:

$$2\ Al + 3\ AgO + 2\ NaOH + 3\ H_2O\ \delta\ 3\ Ag + 2\ NaAl(OH)_4 + 2\ kCal,$$

a parasitic corrosion reaction:

$$2\ Al + 2\ NaOH + 2\ H_2O\ \delta\ 2\ NaAlO2 + 3\ H2 + 200\ kCal.$$

Under these conditions of electrochemical reaction, the effluents are formed by hydrogen gas H_2.

In a non-limiting manner, it is pointed out that the anhydrous sodium hydroxide reserve is advantageously constituted by a mixture of micropellets of anhydrous sodium hydroxide and powder-form stannates charged in bulk into the second chamber forming a reservoir.

The operating mode of the assembly will now be described taking into account the advantageous, but not indispensable, use of the flow regulator 2_3.

At the time when the cell is activated, that is to say, at the time when the opening of the admission valve 3_2 is triggered, after the phase of launching the device, the admission valve 3_2 and the flow regulator 2_3 for the admission of water from the aquatic medium permit the inflow of water from the aquatic medium towards the reservoir formed by the second chamber 2.

By dissolution, this brings about the formation of the activation electrolyte. The flow regulator 2_3 intervenes in order to control the incoming flow of water, regardless of the activation immersion of the device and of course of the

cell for the propulsion of a device in an aquatic medium. The admission valve 3_2 thus ensures the sealing of the reservoir 2 formed by the second chamber 2 during all of the phases of cell storage, including during the launch phase, as will be described later on in the description.

When the whole of the system is started up and the stabilized circulation of the activation electrolyte is established, as described above in the description, the equilibrium of the pressures with respect to the external aquatic medium is the following:

- the reservoir formed by the second chamber 2 is pressurized by the pump 2_4;
- the inlet nozzles of the thermostatic valve 2_8 and of the heat exchanger 2_9 are subjected directly to the above-mentioned pressure;
- the inlet of the main cell or more particularly of the sealed block 2_{11a} forming the electrochemical block is pressurized by the output pressure of the thermostatic valve 2_8, which is equal to the pressure of the chamber 2 forming a reservoir, reduced by the drop in pressure brought about by the thermostatic valve 2_8.

Consequently, the internal cavity of the main cell 2_{11} and of the sealed shell module 2_{11a} forming the latter is subjected as a whole externally to a relative pressure at least equal to the pressure drop 2 brought about by the thermostatic valve 2_8. This condition ensures correct operation of the main electrical cell because the above-mentioned pressure ensures good contact of the stack of electrodes constituting the electrochemical couples, and also good internal electrical conductivity.

The input pressure of the gas separator device 2_7 is reduced by the pressure drop introduced by the stack of electrochemical couples 2_{11b}.

The second outlet 2_{73} of the effluent or gas separator 2_7 is at a pressure substantially close to that of the aquatic medium and a non-return valve permits a slight drop in pressure, for example.

The outlet nozzle for recycled activation electrolyte 2_{72} of the gas or effluent separator device 2_7 is at a pressure substantially close to the pressure for the suction of water from the aquatic medium. Passage through the mode valve 2_6 and also a non-return valve enable a slight drop in pressure to be obtained. At the inlet of the motor-driven pump unit, the connection towards the aquatic medium opened by the admission valve 3_2 at start-up remains open in order, by drawing in water from the aquatic medium, permanently to balance the variations in the internal volume of the cell, in particular of the chamber 2 forming a reservoir. The above-mentioned variations in internal volume are due in particular to an initial degassing of the system in a purging stage prior to the admission of water from the aquatic medium, and due to the volume compensation brought about by the erosion of the electrodes formed by the electrochemical couples which is caused by the electrochemical reactions. The outlet of the mode valve 2_6 and the outlet of the flow regulator 2_3 thus meet at the suction nozzle 2_5 of the motor-driven pump unit 2_4. This joining is effected in a connecting region subjected to the immersion pressure in the chamber 2 forming a reservoir.

All of the command and control functions of the cell are carried out by means of the command and control module 1_1 mentioned above in the description.

More specifically, the above-mentioned module 1_1 ensures the following functions:

- control of the functions of the cell on the basis of the data coming from the control and guide section (not shown) of the device;
- transmission of the cell operating parameters to the above-mentioned control and guide section;
- regulation of the motor-driven pump 2_4 by means of an electronic unit 3_1 located in the third chamber 3.

The above-mentioned operating mode will now be described in conjunction with Figure 1b at points 1, 2 and 3 thereof, for various members making up the assembly shown in Figure 1a.

In particular, the above-mentioned operating mode is described when the admission valve 3_2 is provided with which is associated a start-up valve 3_5 which is itself controlled by a pressure reference formed by a pre-positioning valve 3_6 and when, in addition, a flow regulator 2_3 is mounted on the pipe 2_1 for connecting the admission valve 3_2 and the suction nozzle 2_5 of the motor-driven pump unit 2_4.

The admission valve 3_2 opens the chamber 2 forming a reservoir to the aquatic medium. To be more precise, it permits the entry of water from the aquatic medium into the reservoir, the incoming flow of water being directed towards the flow regulator 2_3 and then towards the motor-driven pump unit 2_4.

The effluent discharge valve 3_3 is coupled to the admission valve 3_2 in order to ensure that the effluent or gas separator device 2_7 is brought into communication with the aquatic medium.

The admission valve 3_2 and the effluent discharge valve 3_3 are fixedly joined, being located diametrically opposite each other on the periphery of the cell body 0 in a longitudinal plane of symmetry of the latter, and they advantageously have an identical opening cross-section, so that the forces due to the pressure of immersion in the aquatic medium are balanced out at every instant. The admission valve 3_2 is controlled by a pyrotechnic activator, for example. It also comprises a start-up valve 3_5 permitting the opening to the aquatic medium of a duct which enables the flow regulator 2_3 to be positioned at the immersion pressure. The start-up valve 3_5 can be controlled by means of a pyrotechnic activator. The pyrotechnic control of the start-up valve 3_5 and the admission valve 3_2 is effected by means of the command and control module 1_1 with a specific time lag.

The pyrotechnic control of the admission valve 3_2 acts on a mechanical device which releases a biasing spring. The assembly formed by the admission valve 3_2 and the effluent discharge valve 3_3, which are connected by the synchronized control 3_4 formed basically by a central rod, moves as far as a mechanical stop. The orifice for the admission of water from the aquatic medium is then open while the orifice for the discharge of the effluents or gases remains closed owing to the action of the external pressure on a valve. The above-mentioned device prevents the entry of water from the aquatic medium *via* the outlet of the effluent discharge valve 3_3 during the start-up phase.

When the second chamber 2 forming a reservoir has been substantially filled, a protective cover arranged at the inlet to the thermostatically controlled activation electrolyte 2_{10} delivered by the thermostatic valve 2_8 is then opened, the recycled electrolyte subsequently leaves the effluent or gas separator 2_7 and an internal pressure occurs in the main cell 2_{11}, which pressure is close to that of the water from the aquatic medium. The degassing flap of the effluent discharge valve 3_3 can then be opened by the action of the spring 3_{30} shown in the drawing. Once open, the flap does not cause any drop in pressure in the degassing circuit.

The start-up valve 3_5 and the admission valve 3_2 each comprise a limit stop contact which indicates their state of activation. The signals of the above-mentioned limit stop contact are sent back to the command and control module 1_1 which monitors the whole of the start-up operation.

The flow regulator 2_3 is intended to limit the flow of water from the aquatic medium admitted into the second chamber 2 by adjusting a passage cross-section adapted to the immersion pressure.

The operating mode of the above-mentioned regulator consists in obstructing the maximum flow cross-section of the diameter of the duct for supplying water from the aquatic medium by the displacement of a slide valve equipped with calibrated orifices. The above-mentioned flow regulator 2_3 is installed in the reservoir. It is connected between the admission valve 3_2 and the suction nozzle 2_5 of the motor-driven pump 2_4.

The start-up valve 3_5 applies the immersion pressure to the slide valve of the regulator by way of a duct for an external pressure reference RPE. The above-mentioned slide valve then occupies an equilibrium position imposed by a spring. The displacement of the slide valve is proportional to the pressure applied. The passage cross-section for the water from the aquatic medium is thus partially closed and the flow is then pre-adjusted within a range of values of from 10 to 15 litres/second.

At the end of the filling operation, when the pressure in the second chamber 2 forming a reservoir is higher than that of the aquatic medium, the regulator re-assumes a completely open position. This later permits an operation in which it is easy to rinse the cell during the performance of a non-destructive mission, for example.

The flow regulation is provided for exterior pressures of the aquatic medium corresponding to immersion depths of from 10 to 350 metres. The adjustment can be carried out for different, lower and/or higher, values. The flow regulator 2_3 comprises an input pressure tap forming a pressure reference of the exterior aquatic medium RPE for the assembly.

The thermostatic valve 2_8 is located at the lower portion of the sealed shell 2_{11a} forming the main cell. It is located in the vicinity of the irrigation orifices of the electrochemical couples 2_{11b} constituting the above-mentioned main cell and thus ensures the entry of the flow of thermostatically controlled activation electrolyte 2_{10} at a substantially constant temperature which may be from 80 to 98°C, for example.

The thermostatic valve 2_8 operates on a purely mechanical principle. It uses a thermostatic probe to control the position of a slide. Depending on the position of the latter, the slide uncovers passage holes at the hot inlet and the cold inlet so that the mixture irrigating the probe is constantly at a defined temperature.

The above-mentioned thermostatic valve 2_8 is equipped at the outlet with a protective cover 2_{80} which can be snapped shut at a predetermined pressure value of the order of 3.0 bar, this protective cover keeping the internal cavity of the electrochemical block closed as long as the pressure in the reservoir is not sufficient.

The thermostatic valve 2_8 is equipped with a filter surrounding the hot inlet orifices of the reservoir. Under these conditions, particles of sodium hydroxide having a size greater than a predetermined value of the order of 300 microns are stopped, while the flow leaving the pump permits permanent unclogging of the filter.

The thermostatic valve 2_8 comprises a temperature probe whose measurement is conditioned by the command module of the electrical propulsion cell 1_1. It also comprises a pressure tap RPBEI at the inlet to the sealed shell 2_{11a} of the main electrical cell, this pressure tap being intended for a pressure sensor CP_6 enabling the mode valve 2_6 to be controlled, as will be described later on in the description.

The nominal regulation temperature maintained by the thermostatic valve for operation of the cell at maximum power and for a low immersion pressure is close to 95°C

while, for a high degree of immersion, the drift of the probe permits operation up to approximately 98°C.

The effluent or gas separator 2_7 collects the activation electrolyte leaving the electrochemical block at the upper portion of the sealed shell 2_{11a} forming that block. It separates the gases or effluents by a cyclone effect as soon as the state of electrolyte circulation is established. It is installed in the reservoir formed by the chamber 2 and composed of a metal, such as stainless steel, in order to ensure good heat conduction and that the activation electrolyte subjected to the phenomenon of effluent separation is maintained at a temperature close to that of the activation electrolyte which is contained in the reservoir but which is not subjected to the phenomenon of effluent separation.

During the start-up phase, the effluent or gas separator 2_7 transfers the effluents or gases from the electrochemical block to the effluent discharge valve 3_3 owing to the position of the mode valve 2_6 which blocks the normal liquid return from the degasser to the motor-driven pump 2_4.

Connected between the outlet of the electrochemical block and the inlet of the gas effluent separator device 2_7 is a suction tube which enables the gases that have remained trapped in the second chamber 2 forming a reservoir to be evacuated. This operating mode is permitted owing to the fact that the pressure in the reservoir is higher than that at the inlet to the gas separator device 2_7. During the cruise phase, this degassing tube provides for leakage inside the system, which leakage is very slight and entirely acceptable, while at the same time ensuring the possible

evacuation of gases which may settle in the second chamber 2 forming a reservoir.

The outlet nozzle 2_{73} of the gas separator device 2_7 is connected to the effluent or gas discharge valve 3_3 through the sealed tube 2_2 and a valve. The above-mentioned tube enables the cell to be rinsed at a rate of the order of 3 litres/second.

The outlet nozzle of the effluent or gas separator device 2_7 delivering the recycled activation electrolyte in the vicinity of the suction nozzle 2_5 of the motor-driven pump is connected to the latter by means of the mode valve 2_6. When the mode valve 2_6 is in the closed position, that is to say, during start-up and during the rinsing of the electrical cell for the propulsion of a device in an aquatic medium, to which the invention relates, the whole of the flow is oriented in the mode valve 2_6 towards the effluent or gas outlet. When the mode valve 2_6 is open, the liquid of the degasser passes through the above-mentioned mode valve and is sucked in by the pump by means of the suction nozzle 2_5 thereof.

The inlet of the gas or effluent separator device 2_7 also comprises a temperature probe CT_7 which is identical to the inlet temperature probe CT_8 located on the thermostatic valve 2_8 and also a pressure tap enabling the output pressure of the electrochemical block, also referred to as RPBEO, to be delivered. This pressure tap enables the operating mode of the cell to be managed by the command module 1_1.

Finally, the mode valve 2_6 is advantageously constituted by a three-way valve having two stable open and closed positions and comprising a slide controlled by an actuating pressure

balanced by a spring. It comprises two simple two-way solenoid valves EV1 and EV2 enabling the application of the actuating pressure to the above-mentioned slide to be managed.

The solenoid valve EV1 connects the tap for immersion pressure RPE of the flow regulator 2_3 to the chamber of the mode valve 2_6. The solenoid valve EV1 is a valve which is normally open in the absence of electrical power.

The solenoid valve EV2 connects the input pressure tap of the electrochemical block, that is to say, the output pressure of the thermostatic valve 2_8, also referred to as RPVT, to the chamber of the mode valve 2_6. The solenoid valve EV2 is a valve which is normally closed.

The mode valve 2_6 enables the activation electrolyte leaving the outlet nozzle 2_{72} of the gas effluent separator device 2_7 to be oriented in accordance with two paths corresponding to operating modes of the cell:

- in the upper or closed position, no pressure is applied to the mode valve 2_6. Under these conditions, the mode valve 2_6 orients the effluent flows towards the gas discharge valve 3_3. This mode of operation takes place during start-up in order to purge the gases to the aquatic medium, and at the end of the mission, during the rinsing of the cell in the case of a non-destructive mission.

- in the lower or open position, the mode valve 2_6 receives the actuating pressure which positions its slide in the lower position and it orients the electrolyte towards the inlet of the motor-driven pump, i.e. the suction nozzle 2_5,

so that the activation electrolyte circulates in a closed loop in the cell.

The two solenoid valves EV1 and EV2 are completely controlled by the command module 1_1. According to the scheme shown at point 3 in Figure 1b:

- during the activation phase, that is to say, the phase of launching the device, the valve EV1 is supplied with power and therefore closed, which prevents the input pressure of the flow regulator 2_3 from acting on the slide of the mode valve 2_6. On the other hand, the solenoid valve EV2 is not supplied with power and is therefore closed, while waiting for a command signal delivered by the command module 1_1. Under these conditions, the mode valve 2_6 is not under stress and remains in the upper or closed position. It will be appreciated that the supply of electrical energy to the solenoid valve EV1 by the auxiliary cell 1_0 is permitted as of the initial start-up thereof;
- at the end of the operation of filling the reservoir formed by the second chamber 2, when the pressure conditions are detected, the solenoid valve EV2 is supplied with power, which enables the input pressure of the electrochemical block, that is to say, the input pressure RPVT, to be applied to the slide of the mode valve 2_6. The slide tilts and therefore enables the recycled activation electrolyte coming from the effluent or gas separation device 2_7 to pass to the pump 2_4. The solenoid valve EV1 for its part remains closed.

At the end, for example, of a non-destructive mission, the supply of power to the first solenoid valve EV1 is cut, which decompresses the chamber of the mode valve 2_6 and enables the slide to go back up to the upper position. The

activation electrolyte is then evacuated by way of the effluent or gas outlet, that is to say, by way of the effluent discharge valve 3_3. At the same time, the supply of power to the solenoid valve EV2 is cut, which then prevents the input pressure of the electrochemical block, that is to say, the pressure RPVT, from acting on the slide of the mode valve 2_6.

The solenoid valves EV1 and EV2 are controlled by the above-mentioned command and control module 1_1 which operates on the basis of the pressure data coming from the pressure taps below:

- tap for reservoir pressure;
- tap for immersion pressure RPE;
- tap for the output pressure RPBEO of the electrochemical block.

Two differential pressure sensors which are not shown in the drawing enable the following data to be supplied to the command and control module 1_1 from the above pressure taps:

- the difference between the reservoir pressure and the immersion pressure indicates the state of operation of the circulation loop. This difference in pressure must tally with the state of the cell and with the flow control of the pump;
- the difference between the output pressure of the electrochemical block and the immersion pressure indicates the filling state of the cell.

The operating mode and the control of the second solenoid valve EV2 by the command module 1_1 which brings about the

switching of the mode valve 2_6 are effected on the basis of the following criteria:

- the difference in pressure between the outlet of the electrochemical block and the aquatic medium;
- the monitoring of the electrical voltage delivered by the electrochemical block;
- the monitoring of the output temperature of the electrochemical block;
- the chronology of start-up.

By way of summary, the control logic of the mode valve 2_6 through the supply of electrical power for controlling the two solenoid valves EV1 and EV2 is given hereinafter in accordance with the following Table:

1. Initial state	EV1=0	EV2=0
2. As soon as the thermal cell voltage is OK	EV1=1	EV2=0
3. As soon as pressure "output BE-immersion" is OK	EV1=1	EV2=1
4. As soon as the order to stop reaches the module 1_1	EV1=0	EV2=0

In addition, the lower position of the slide of the mode valve 2_6 is detected by means of a magnetic sensor CM_6 and is acquired by the command and control module 1_1.

The operating mode of the assembly is represented with reference to points 1), 2) and 3) of Figure 1b in which:

- represented at point 1) are the launch and cruise phases, respectively, of the device; the launch phase may last a few

seconds or a few tens of seconds and the cruise phase may last several tens of minutes;

- represented at point 2) is the graph of the voltages delivered by the auxiliary cell and the main electrical cell, respectively, it being understood that the nominal voltage V'N of the auxiliary cell of the order of 165 V is substantially different from that of the main electrical cell 245 V, for example.

Represented at point 3) is the control of the two solenoid valves V1 and V2 constituting the mode valve 2_6 according to the above Table.

As regards the motor-driven pump 2_4, this pump ensures the circulation and recycling of the activation electrolyte at a variable flow rate. It may be constituted by a centrifugal pump immersed in the electrolyte reservoir and by a likewise immersed motor. The motor is a motor of the type whose speed is controlled as a function of the pumping requirement. The electronic control system of the motor is denoted by the unit 3_1 and located in the chamber 3, for example.

The supply of power to the pump motor is advantageously effected from the main electrical network of the main cell at 400 V while the supply of power to the electronic control system may be effected on the auxiliary circuit of the cell at 200 V. In particular, when the main cell has taken over from the auxiliary cell, the secondary network may be supplied with power from the half-voltage delivered by the main cell.

Finally, the motor-driven pump 2_4 is controlled in terms of speed by the command module 1_1 by means of a series RS422 connection of the conventional type.

The motor-driven pump may be controlled in accordance with discrete operating states with incremental flow.

The motor-driven pump 2_4 provides data relating to:

- absorbed current;
- rate of rotation;
- temperature of the circuits for supplying power to IGBT converters (Insulated Gate Bipolar Transistor);
- self-test evaluation.

The starting of the motor-driven pump 2_4 is controlled by the command and control module 1_1 as soon as the latter receives the contact signal provided by the opening of the admission valve 3_2.

A more detailed description of the structure of the electrical cell for the propulsion of a device in an aquatic medium and of a method of using that structure in accordance with the subject-matter of the present invention will now be given hereinafter.

As shown in Figure 1a, the sealed cell body 0 is advantageously formed by an assembly of elements constituted at least by a front collar 0_1 and a front end 0_2 of the main electrical cell, the front collar 0_1 and the front end 0_2 forming the third chamber 3 mentioned above.

The sealed cell body 0 also comprises a central shell 0_3 and a rear end 0_4, the front end 0_2, the central shell 0_3 and the rear end 0_4 forming the second chamber 2 constituting the reservoir.

Finally, the sealed cell body 0 comprises a rear collar 0_5, the rear end 0_4 and the rear collar 0_5 constituting the first chamber 1.

As also shown in Figure 1a, the central shell 0_3 at least is constituted by a metal alloy which is a good heat conductor. A portion at least of the central shell 0_3 which is located in the vicinity of the main electrical cell 2_{11} and in particular of the electrochemical block forming that cell constitutes the heat exchanger with the aquatic medium and in particular the heat exchanger 2_9 for at least the derivative flow of activation electrolyte.

It can be seen in Figure 1a that the derivative flow of activation electrolyte is generated by the pressure produced by the motor-driven pump 2_4 in a gap 2_{91} formed at the lower portion of Figure 1a, between the wall of the central shell 0_2 and a metal wall fixedly joined to the thermostatic valve 2_8, and finally to the sealed body 2_{11a} forming the electrochemical block 2_{11}. The above-mentioned gap 2_{91} permits the generation of the derivative flow of activation electrolyte at a substantially constant temperature acting as the reference temperature for the above-mentioned thermostatic valve 2_8.

Preferably, the front collar 0_1, the front end 0_2 of the electrical cell, the central shell 0_3 and the rear end 0_4 and also the rear collar 0_5 are composed of a metal material. The external face thereof which is to be in contact with the aquatic medium is advantageously provided with a protective anti-corrosion layer obtained by hard anodic oxidation.

As regards the central shell 0_3, it should be mentioned that this shell, between the front end and the rear end, is

formed in a single piece and has no opening at the periphery in order to ensure that the assembly is sealed during all of the phases of storing the cell for the propulsion of a device in an aquatic medium according to the subject-matter of the present invention. This specific design enables double sealing of the reservoir formed by the second chamber 2 with respect to the external aquatic medium to be put in place at the joints with the front end 0_2 and the rear end 0_4.

As shown in Figure 1a, the cell body and, in particular, the second chamber 2, is provided with a double sealing barrier with respect to the external aquatic medium.

A first sealing barrier, marked B_1, is formed by a seal between the aquatic medium and the first chamber, and the third chamber, respectively, and a second sealing barrier, B_2, is formed by a seal between the first and second chamber and the second and third chamber, respectively. The above-mentioned sealing barriers are represented by specific hatching in Figure 1a.

Finally, the internal face of the central shell 0_3, except for the portion forming the heat exchanger 2_9, also comprises a thermally insulating coating at the portion forming a reservoir for the activation electrolyte. The purpose of this thermally insulating coating is to reduce the cooling of the stored activation electrolyte by heat exchange with the aquatic medium during the cruise phase. This thermally insulating coating may be constituted by a coating of the epoxy resin type, for example.

In addition, the internal face of the front end 0_2 of the electrical cell of the central shell 0_3 and of the rear end

0_4 of the electrical cell constituting the second chamber 2 forming a reservoir comprises a chemical nickel coating for protection against corrosion by the anhydrous sodium hydroxide.

The sealing of the second chamber 2 forming a reservoir may then be managed in the following manner:

- the reservoir is the portion of the electrical cell for the propulsion of a device in an aquatic medium according to the subject-matter of the present invention that comprises the active components of the cell, in particular the sodium hydroxide and the electrochemical block. For this reason, the elements making up the above-mentioned reservoir have been organized in such a manner that, together, they have total sealing in respect of storage in water from the aquatic medium owing to the two sealing barriers B1 and B2 mentioned above which are formed by specific seals.

In the case of inadvertent immersion, in particular of the reservoir portion, no electrochemical material is in contact with the water from the aquatic medium. Two water detectors, one located at the front and the other located at the rear, that is to say, in the chambers 1 and 3, for example, are connected by specific wiring, on the one hand, to the command and control module 1_1 and, on the other hand, to the external launch system, which can thus monitor the safety of the cell before the device is launched.

The second sealing barrier B2 ensures the integrity of the reservoir function with respect to the external aquatic medium.

A pressure switch, which is not shown in the drawing, may be provided in order to permit permanent control of the sealing of the mode valve 2_6. The above-mentioned pressure switch is connected between the two seals of the mode valve 2_6, on the one hand, on the water inlet portion, that is to say, on the outlet nozzle 2_{72} of the effluent or gas separator 2_7 to which the above-mentioned mode valve 2_6 is connected, and, on the other hand, on the gas outlet portion 2_{73} of the above-mentioned separator 2_7. The double sealing barrier B1 and B2 equipped with the above-mentioned water and pressure detectors ensures a high level of reliability in terms of the sealing of the electrical cell for the propulsion of a device in an aquatic medium to which the present invention relates.

Finally, the front collar 0_1 and the rear collar 0_5 have, as shown in Figure 1a, a distal end which is open with respect to the front end 0_2 and the rear end 0_4, respectively, of the cell. This embodiment enables the electrical propulsion cell to which the invention relates to be constructed in the form of an independent module which can be stored as a substantially inert component with its charge of anhydrous sodium hydroxide reserve when the electrical propulsion cell is not mounted with the device, and also in the form of an element integrated directly in the body of the device in the opposite case. To that end, in a non-limiting embodiment, the front collar 0_1, the central shell 0_3 and the rear collar 0_5 advantageously have a substantially cylindrical cross-section of revolution. The above-mentioned shape is particularly suitable for integration in the body of the device when that device is constituted by a torpedo, for example, or by an underwater observation device. In this situation, the distal end of the front collar is secured mechanically and coupled electrically to the active portion

of the device and the distal end of the rear collar is secured mechanically and coupled electrically to the propulsive and control rear portion of the device in order to constitute an electrical propulsion cell which can be activated as soon as the device is launched in the aquatic medium.

It will be appreciated in particular that the assembly represented in Figure 1a comprises wire connections by cables and/or by buses, as mentioned above, between the first chamber 1, the second chamber 2 and the third chamber 3, although these connections as a whole are not all represented in the drawings.

Under these conditions, the cell for the propulsion of a device in an aquatic medium according to the subject-matter of the present invention comprises temperature sensors for the flow of activation electrolyte entering and leaving the main electrical cell, in order to be able to regulate the temperature of the flow of activation electrolyte by means of the thermostatic valve 2_8.

The cell also comprises sensors for sensing the relative pressure of the activation electrolyte in the second chamber 2 forming a reservoir for that same activation electrolyte at the inlet of the device 2_7 for the circulation of the activation electrolyte and for the separation of the effluents, these sensors of relative pressure delivering a relative pressure with respect to the pressure outside the sealed cell body, that is to say, with respect to the pressure reference RPE mentioned above in the description.

Finally, the cell comprises a plurality of contacts or of detection of a contact for sealing the valve 3_2 for the

admission of water from the aquatic medium, a contact for opening the valve for the admission of water to the above-mentioned sealed cell body 2_{11a}. Of course, all of these sensors and/or contacts are connected by suitable connections provided with sealed bushes in a manner known *per se*.

Sealed electrical power bushes such as shown in Figure 1a under the references 1_2 and 1_3 connect the auxiliary cell 1_0 to the set of elements contained in the second chamber 2 forming a reservoir and the third chamber 3 or front chamber for supplying electrical power to the electronic module 3_1 of the motor-driven pump 2_4, the sealed electrical bush 1_3 being connected directly to the electrochemical block and in particular to the electrochemical couples in order to deliver the electrical power energy to the propulsion unit of the device carrying the electrical cell for the propulsion of a device in an aquatic medium according to the subject-matter of the present invention. The propulsion energy is supplied by means of a power connector provided with an intensity sensor CI as shown in the drawing of Figure 1a.